

Computer-games for gravitational wave science outreach: *Black Hole Pong* and *Space Time Quest*

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Abstract. We have established a program aimed at developing computer applications and web applets to be used for educational purposes as well as gravitational wave outreach activities. These applications and applets teach gravitational wave physics and technology. The computer programs are generated in collaboration with undergraduates and summer students as part of our teaching activities, and are freely distributed on a dedicated website. As part of this program, we have developed two computer-games related to gravitational wave science: ‘Black Hole Pong’ and ‘Space Time Quest’. In this article we present an overview of our computer related outreach activities and discuss the games and their educational aspects, and report on some positive feedback received.

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1. Introduction

The next generation of gravitational wave (GW) detectors - most notably Advanced LIGO [1], GEO-HF [2] and Advanced VIRGO [3] - are expected to achieve the first direct detection of GWs during 2015, when Advanced LIGO begins operation or soon thereafter, giving life to the new field of the GW astronomy. The impact on cosmology, fundamental physics, and of course on conventional astronomy itself will be enormous; the interest in GW observation is therefore growing rapidly in the scientific community. But while the public interest in cosmology and relativity is high, public knowledge of the principles behind GW detection is still rather limited, and even the existence of the large GW observatories is little known by the more general public, compared to larger experimental facilities such as, for instance, the Large Hadron Collider [4]. There is a clear need to better inform and inspire the general public and prospective students in GW astronomy and related sciences. Within the LIGO Scientific Collaboration (LSC) the ‘Education and Public Outreach’ (EPO) group aims to combine ideas and approaches across the collaboration to successfully communicate the vision and benefits of GW observation throughout the world.

To contribute to these international efforts in the promotion of GW astronomy, at the University of Birmingham we have established a unique program aimed to the development of small educational computer applications that can be used to illustrate the basics of GW science and GW detector technology in a playful but informative way. The aim is to present GW

science to younger generations within one of the environments they are more familiar with, i.e. computer-games, and to exploit the communication channels that the *new technologies* offer to possibly get an even larger international audience in contact with GW science.

This activity led us to the successful development of a number of interactive computer applets describing a variety of concepts connected to GW science and, eventually, to the realisation of two full-scale computer-games based on the subjects of gravity and GWs. In this article we overview our computer related outreach activity and present and discuss our GW related games, Black Hole Pong and Space Time Quest.

2. ‘Processing’ programs for science outreach

The idea of developing small computer applications for educational purposes builds upon the need to introduce new students to the world of computer programming and modelling of physical systems in a manner which is enjoyable. This will not only help them learn successfully, but also engages them with GW research. During the initial ‘induction’ phase, undergraduate or summer-students involved in research projects with our group are encouraged to generate a small computer program on a GW subject of their interest, which is then developed, as a conventional student-project, by the student with the supervision of more senior members of the group.

The small computer programs, called ‘sketches’, are developed using the open-source programming environment Processing [5, 6], originally developed at the MIT Media Lab in 2001 as a software prototyping environment and to teach fundamentals of computer programming within a graphical context. Processing has eventually reached a wide audience and is now largely used in many professional communities, such as designers, artists, and architects to create graphical applications, animations, interactive tools and for visual arts in general. Processing offers an intuitive approach to programming for the beginner or an efficient sketchbook for rapid prototyping by experienced programmers. Thus Processing allows students with very different computing-backgrounds to collaborate and to successfully produce graphically impressive sketches in a relatively short period of time.

The successful sketches are published online on our outreach website gwoptics.org [7], on individual webpages where the student-author can provide instructions and a short description of the physics illustrated in the sketch. The program is either embedded within the HTML code to run as an applet in the webpage itself or, where more appropriate, distributed for download as an application to install and run on the computer of the interested person.

The collection of sketches developed so far covers a wide spectrum of subjects related to GW science and technologies. The programs range from illustrating the most fundamental properties of GWs, for example the deformation of space-time produced by a propagating GW or the characteristic ‘sound’ of the GW signal of colliding black holes, to the illustration of the vital technologies and phenomena used in GW detectors such as lasers, vibration isolation systems or interference of light. Different combinations of these sketches have been successfully used as interactive tools during seminars about GW detection and during more general lectures in schools and universities, and the sketches webpages are regularly consulted online by people interested in learning about the specific subject.

3. The gravitational wave games

The positive feedback we received about the different interactive sketches has encouraged us to realise two properly defined computer-games based on subjects related to gravity and GW science. The motivation behind the development of the two particular games was as follows: in one case, the aim was to produce an intuitive and graphically attractive computer-game that could engage and entertain children and teenagers during science exhibitions; in the other, the goal was vice-versa to develop an interactive element that could function as an engaging and playful supplement for illustrating and explaining the secrets of GW detectors and their

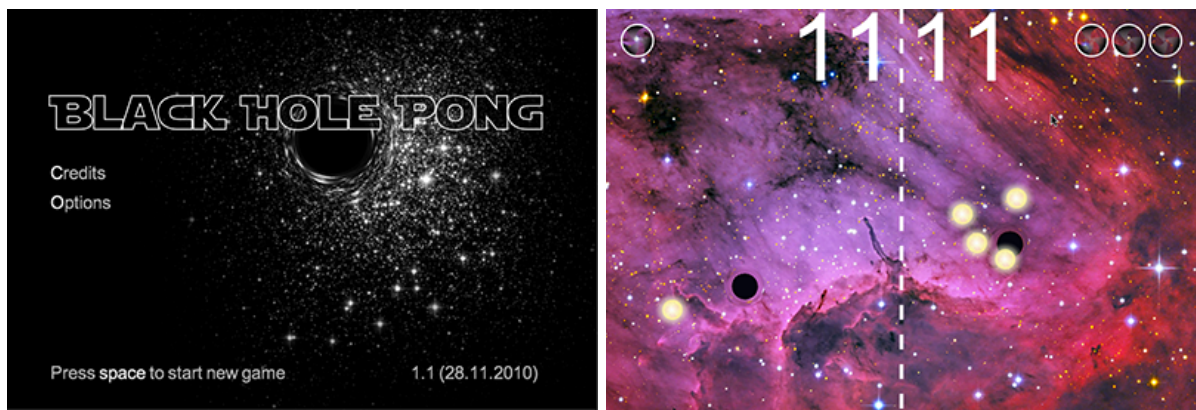


Figure 1. Screen-shots of the Black Hole Pong game. The image on the left shows the start-up screen of the game and the right snapshot has been taken mid-game, showing one of the astronomical background images, the two ‘black holes’ controlled by the players and several bright disks as the stars currently in play.

technology to a more educated audience, such as high-school students onwards. The two games, Black Hole Pong and Space Time Quest, are presented and discussed in this section.

3.1. *Black Hole Pong*

Black Hole Pong (BHP) is a new arcade-style game with a reference to one of the very first computer-games, *Pong* [8]. Pong involved two players, each one controlling a paddle which they would move vertically up and down in order to bounce a ball back towards their opponent: each time the ball touched the opponent’s far edge of the screen, the player would score a point. In BHP the idea of the split-screen has been kept. However each player controls a black hole which can move horizontally as well as vertically, and the objective is to make use of the gravitational potential of the black hole to fling free roaming stars towards the other player.

BHP has been designed as a simple, fun game for people of all ages. At the same time, BHP features several educational elements that make it a fascinating tool for teaching, learning and discovering new physical concepts. For example, by learning how to manoeuvre the incoming stars only using the black hole’s gravitational potential, the player develops an intuitive



Figure 2. Children, students and adults enjoying the BHP game at the University of Birmingham Community Day 2011 (left), the British Science Festival 2010 (center) and the 9th Amaldi Conference (right).



Figure 3. Screenshots of STQ. On the left, the ‘PI’s office’ is the game’s hub from which the player can access all the detector’s subsystems. On the right an image of the ‘Optics’ subsystem screen.

understanding of concepts such as gravitational attraction, orbital mechanics and gravitational slingshot effect. The background graphics of the game is a slideshow containing images of the night sky as well as astronomical objects taken by both amateur astronomers and large ground/space based telescopes. Furthermore, several astrophysical phenomena are graphically featured in the game, such as ‘worm holes’, ‘star capture’ and ‘gravitational lensing’, adding to the overall simple but attractive graphics, see Fig. 1. When used as part of an exhibition, science fair or similar activity we have supported the arcade-style attraction by state-of-the art hardware: the game is designed to be controlled with the well-known Microsoft Xbox controllers and whenever possible we use large Apple iMac computers to run the game, as shown in Fig. 2.

3.2. *Space Time Quest*

Space Time Quest (STQ), here shown with screenshots in Fig. 3 and Fig. 4, is a manager-simulation type game: the player is the ‘Principal Investigator’ (PI) of a future ground-based GW interferometer who has the goal to design the most sensitive GW detector. The PI is assigned a limited budget that he has to wisely distribute between the different detector’s subsystems to tweak the instrument parameters and to achieve the best sensitivity. Once the player is satisfied with their design, they can operate the detector in ‘Science-Run’ mode and see how well it performs: the final score is determined by how far in the universe the detector itself can explore, based on the achieved sensitivity curve, and it is recorded in the web-based STQ ‘hall-of-fame’.

STQ is complemented by the ‘Gravitational Waves E-Book’ [9], effectively a collection of webpages with short introductions to a number of topics relevant to GW science. The E-Book offers a description of the main instrument subsystems that comprise the detector and illustrates how each noise source relates to the different subsystem parameters that the player chooses. The E-Book text is purposely aimed to the general person who has interested in GW science, and as such it is written with a simple style to make it accessible to a broad public of all ages and backgrounds. The E-Book is also independently available online as more general reading material on GW science, and is now also offered in multiple languages.

STQ contains many educational merits for the public. First of all, the game showcases the physics behind a real GW detector and it presents all the main subsystems that comprise it. Furthermore, it illustrates all the most important noise sources which can limit the detector’s sensitivity. By reading the E-Book and by looking at the changes in the sensitivity curve, the player can see how each subsystem is affected by the different noise sources, and discover

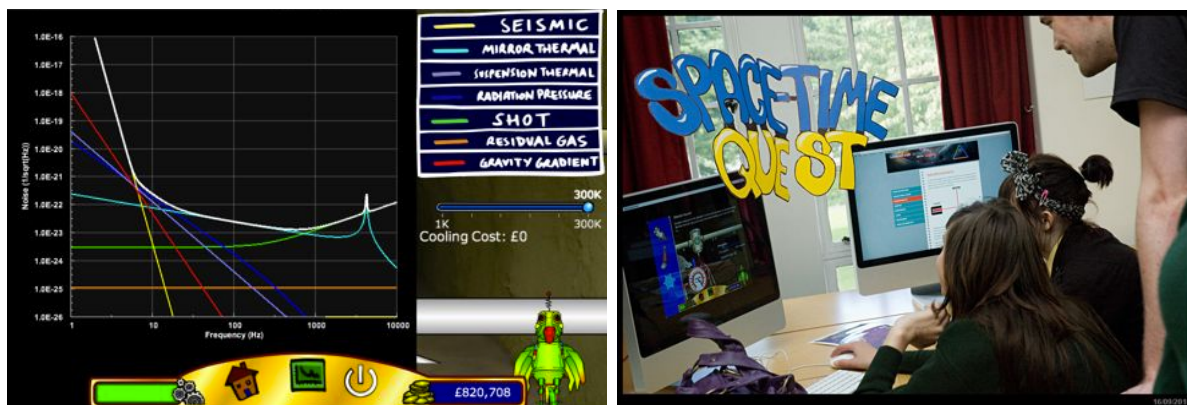


Figure 4. Left: a screen-shot of the ‘sensitivity curve’ in the STQ game. Right: school students playing STQ with a demonstrator during an exhibition at University of Birmingham.

some of the ways in which physicists try to reduce the noise sources in the detector. The game also presents some of the typical challenges that physicists face when designing a real physics experiment, such as making trade-offs between performances of different interlinked subsystem parameters and managing the available resources wisely. Finally, STQ features images of astronomical objects in the background, similar to BHP. Furthermore the STQ graphics are based on photographs of components from real GW detectors complemented with realistic cartoons of the detector parts, offering a realistic picture of how a GW interferometer looks like to the user.

STQ is mainly targeted for science teachers, A-level, Higher and Advanced Higher science students and is mainly suited for use in science fairs and exhibitions and initially played with the help of demonstrators. However, STQ has also proved to be an entertaining tool to teach the basics of GW science also to beginners in GW research-projects and PhD schools, or to attract prospective research students towards the GW field.

4. Use in exhibitions and distribution

Early prototypes of the games have been used for the first time during the exhibition about GW science ‘Looking for Black Holes with Lasers’, organised by the Birmingham GW Group within the ‘British Science Festival’, held in Birmingham in September 2010 [11]. The very positive feedback collected with the games during this first exhibition gained us the attention of our university and of local schools and associations. This led to our displays being routinely used in University Open/Admission days and in our university’s outreach events, e.g. the University

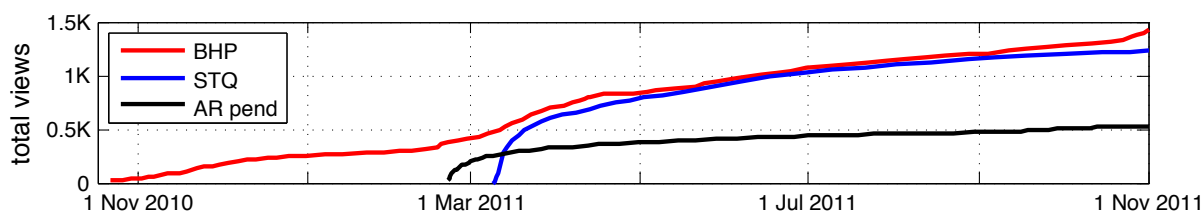


Figure 5. Total number of unique views of the online video tutorials for the Black Hole Pong and Space Time Quest games and for one of our processing sketches, the ‘Augmented Reality Pendulum’. Data from youtube.com.

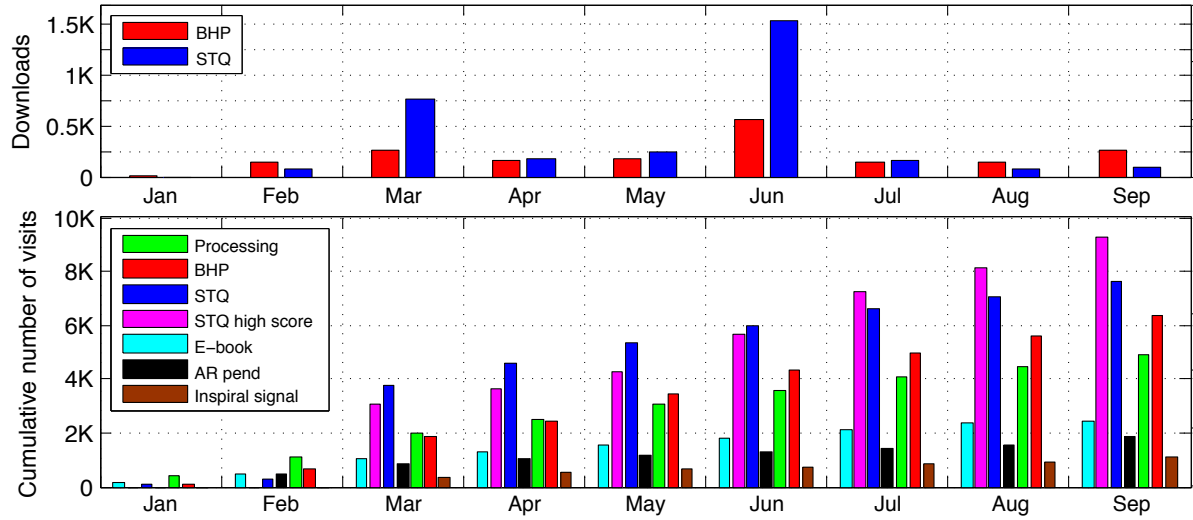


Figure 6. Top panel: number of download of the Black Hole Pong and Space Time Quest games over the year 2011. Bottom panel, cumulative number of visits during 2011 to some of the gwoptics.org outreach pages, such as the main page collecting all Processing programs, the games BHP and STQ, the STQ high-score ‘hall of fame’, the E-Book and the pages of two other Processing sketches, the ‘Augmented Reality Pendulum’ and the ‘Inspiral signal’.

Community Day 2011 [12], and gained members of our group invitations to visit schools and give public seminars, where the games were used to complement the seminar. At the same time, positive feedback has been received from school teachers concerning our other Processing sketches which have been used as support material in physics lectures and during science activities.

Since their official release, BHP and STQ are freely distributed on our website gwoptics.org and on the outreach pages of the ligo.org website [13], which hosts links and multimedia material of interest for the EPO group. The launch of the two games was also announced online via social-media networks and with online videos, with the main aim of raising both the profile of the games and its visibility. Indicative figures of merit on how positive this campaign has been can be inferred from the total number of download of the two games, the entries in the high score ‘hall of fame’, the unique views of the online video-tutorials, and more generally from the number of visits to the webpages presenting our online material. Examples of such data are presented in Fig. 5 and Fig. 6. The response is so far very positive and seem to indicate a slow but constant growth of new contacts and an increasing interest in the products themselves. In particular, sensible increments in the number of contacts can be successfully correlated with our contribution at science events and exhibitions, with release of new outreach material and with our communication campaign via online social networks.

STQ and BHP are also accompanied by short questionnaires, handed-out at exhibitions and during visits to schools as well as online, which are distributed to collect anonymous feedback amongst the users, targeting in particular teacher’s and student’s categories. The aim of the questionnaires is primarily to evaluate the success of the games among the users and in particular about the effectiveness of their educational aspects. As a further step in the future, the goal is to develop a proper analysis of the feedback provided in the questionnaires that will allow us to better link the games to specific elements of education, such as formal education, and to improve their integration within the syllabus.

5. Conclusion and future activities

Our program aimed at the development of small computer applications for educational purposes. This has been successful, with the realisation of several interactive sketches and two full scale games related to GW science and technology. Thanks to our participation at popular science events, and to our online presence and communication campaign, the sketches and the games are now becoming popular within schools and science associations and, as shown by the response gathered from the online audience, the prospective feedback looks promising for the future. In particular, BHP and STQ have allowed us to significantly increase the visibility of our online presence and as such also of GW science within the general public, as well as within the local scientific community.

Encouraged by these positive results, we will continue our computer related outreach activity in the next years, and we plan to realise new Processing sketches for outreach in the near future. In parallel, BHP and STQ will be treated as running projects. We will take advantage of the feedback and advice from teachers, students and other users to make further modifications and improvements to both games. Furthermore, we will continue presenting BHP, STQ and our other interactive sketches during visits to local schools and in popular science events. We hope to increase and improve our online communication campaign on GW subjects to make GW detectors more and more popular among the general public and to gain GW science the largest audience possible.

Acknowledgments

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